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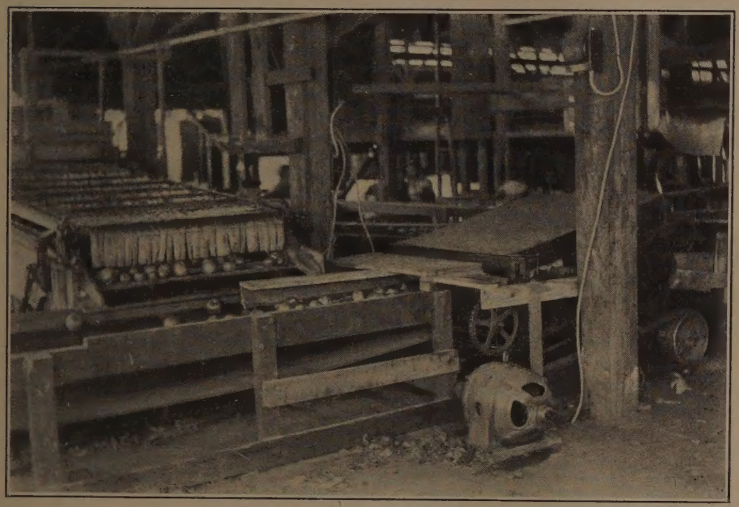

To remove visible residues persisting from sprays of oil plus Bordeaux mixture, the apples after leaving the washer (on the left) were conveyed through a two-way polishing machine (on the right, above the motor).

Spray Residues and Their Removal From Apples

By Walter S. Hough

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Spray Residues and Their Removal From Apples

By Walter S. Hough, *Entomologist*[1]

Introduction

In September, 1934, complaints came to our attention that apples were turning black at the calyx-end after the fruit had passed inspection at the time of packing. This condition was usually first observed by the buyer when the fruit arrived on the market[2] and, as a result, sales were impaired. Faulty operation of washing machines was suspected as possibly having something to do with some of the cases involved. Investigations were started at once on the operation of various types of washers found in northern Virginia and were continued to the end of the season of 1935. The results are given in this bulletin. Included also are results contributing to the answers to certain questions frequently asked on the subject of spray residues and residue removal.

Relation of the Spray Schedule to Spray Residue

"How late in the season can I spray with lead arsenate and still not have to wash the fruit?" The correct answer to this annual question depends on a number of factors including thoroughness of spraying and the materials used with lead arsenate such as Bordeaux mixture, a sulphur fungicide, lime, oil, or a sticker. From a practical standpoint the best approach to an answer lay in obtaining definite records from a number of the better-sprayed orchards in various parts of the state as to the time of each spray, the materials used, and the residue on each variety at picking time. In most of the orchards a sulphur fungicide was usually used up to about June 1, after which Bordeaux mixture was used. In some of the orchards summer oil was used in the first two cover sprays in 1934 and in the second and third cover sprays in 1935 and the resulting residues were usually somewhat higher than in orchards where no oil was used. Table 1 shows the average lead residue on the fall and winter varieties and also the maximum amount found on fruit from the orchards included in the investigation. The analyses of residue included arsenic as well as lead but only the latter is included in the table, because the ratio of lead to arsenic was about 2:1 and with the present tolerance of 0.018 grain of lead and 0.010 grain of arsenic per pound of fruit, it was obvious that lead residue is the factor limiting the use of lead arsenate. All analyses were made by the State Depart-

[1]The writer desires to acknowledge the generous cooperation of W. Catesby Jones, chief chemist, and J. R. Lindsay, chemist, of the Virginia State Department of Agriculture and Immigration, who made hundreds of analyses of lead and arsenic residues for the sole purpose of aiding this investigation. Dr. W. J. Schoene, R. H. Hurt and A. M. Woodside assisted in assembling data on the relation of spray schedules to spray residue in their respective parts of the state. Dr. A. B. Groves contributed the photograph used in Figure 1. For the determination of fluorine residue the author is indebted to the U. S. Bureau of Entomology and Plant Quarantine, to Prof. G. A. Shuey of the University of Tennessee, to the Pennsylvania Salt Manufacturing Company of Philadelphia, and to the Kalo Company of Quincy, Illinois.

[2]Proceedings of the 39th Annual Meeting of the Virginia State Horticultural Society, page 31, published in January, 1935.

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ment of Agriculture in the course of the regular fall survey of the residue situation. Six to a dozen analyses were made from a number of orchards depending on the number of varieties grown.

It has been known for some time (Va. Exp. Sta. Bul. 278) that a third cover spray of lead arsenate applied during the latter half of June would not, under Virginia conditions, necessitate washing to clean the fruit to within the arsenic tolerance. The data in Table 1, however, show clearly that the same schedule of three cover sprays will require washing the fruit to remove excessive lead residue in the better-sprayed orchards. Data in Table 1 also show that a lead residue near or exceeding the present tolerance is to be expected from lead arsenate applied in the calyx and two cover sprays ending about June 11 or 12. In other words this is about the latest date that lead arsenate can be used on fall and winter varieties without necessitating the washing of the fruit. In certain cases, for example, if oil has been used with lead arsenate, it may be necessary to wash the apples even though the last application was completed not later than June 12. If the lead tolerance is eventually reduced to 0.014 grain per pound of fruit, it is apparent from the figures in Table 1 that lead arsenate could not be applied after the first cover spray ending late in May without necessitating the washing of the fruit.

Table 1.—Relation of the spray schedule to the lead residue on the apples at picking time. Data taken from commercial orchards in various parts of Virginia, excepting those marked[1] which are from experimental orchards. Fruit picked in September and October.

Sprays containing lead arsenate (used at the rate of 3 lbs. per 100 gals.)	Average date when last lead arsenate spray was completed		Lead residue at picking time (Grain per pound)			
			Average		Maximum	
	1934	1935	1934	1935	1934	1935
Calyx spray[1]	May 10	May 13	.007	.007	.009	.007
Calyx and 1 cover spray[1]	May 28	May 27	.010	.012	.015	.017
Calyx and 2 cover sprays	June 12	June 11	.019	.013	.027	.027
Calyx and 3 cover sprays	June 30	June 25	.026	.024	.030	.048
Calyx and 4 cover sprays	July 19	July 31	.040	.032	.080	.068
Calyx and 5 cover sprays	July 28	July 30	.048	.057	.056	.058
Calyx and 6 cover sprays	Aug. 18	----------	.079	----------	.094	----------
Calyx and 7 cover sprays	Aug. 15	----------	.083	----------	.094	----------

One important fact, evident from the study of the relation of the spray schedule to spray residue, was the relation of the time of applying the last spray to the residue remaining on the fruit at picking time. Apples which had received the calyx and two cover sprays ending late in June carried about the same amount of residue as fruit which had received an additional cover spray within the same period of time. Likewise, the calyx and four cover sprays ending in early July caused little or no more residue than the calyx and three covers ending at the same time. In short, the time of completing the last cover

spray up to early July was more closely related to the amount of residue at picking time than the number of sprays which preceded that date.

Summer oil increased the adherence of lead arsenate and its use (in two cover sprays in June) involved the necessity of washing the fruit. In one orchard oil was used in late July, 1934, and the lead residue amounted to 0.080 grain per pound of fruit or about twice the average amount found on fruit from most well-sprayed orchards receiving the same number of lead arsenate applications without oil.

Summer varieties (Transparent, Duchess, and Wealthy) clean more readily than fall and winter varieties, but experience has shown that lead arsenate applied as late as June 12 may result in a lead residue in excess of the present tolerance.

Cryolite (sodium fluoaluminate) has been used somewhat as a substitute for lead arsenate. The active ingredient is fluorine, for which a tolerance of 0.010 grain per pound of fruit has been allowed. Growers, who use lead arsenate in the early cover sprays and then, to avoid washing, turn to cryolite, are confronted with the question concerning the number of cryolite sprays which can be applied without exceeding the fluorine tolerance. Information relating to this question is given in Table 2. It will be seen that two cover sprays applied June 18 and July 20 may result in a fluorine residue equal to the tolerance, and that three sprays ending July 25 or 26 exceeded the tolerance to the extent that washing was necessary. The use of fish oil as a sticker greatly improves the insecticidal value of cryolite on apples, and 1 quart of the fish oil has been much more effective than 1 pint per 100 gallons. But it appears from the results obtained in 1934 that two sprays of cryolite plus 1 quart of fish oil per 100 gallons, applied in June, would likely cause a fluorine residue sufficient to require removal by washing.

Operation of Fruit Washers

The acid bath.—The commercial grade of hydrochloric acid (also known as muriatic acid) used in washing apples has a density test of 20° Baume and usually contains between 31 and 32 percent acid by weight. When one gallon is added to 100 gallons of water the result is a solution containing about 0.36 percent acid by weight. Two gallons in 100 gallons of water make a solution testing about 0.72 percent and a solution containing three gallons in 100 gallons of water tests about 1.08 percent acid. The percentage of acid resulting from the addition of various quantities of the commercial hydrochloric acid to 100 gallons of water is shown in Table 3, which may be of value in estimating the acid strength of the washing solution and also in estimating the amount of acid that should be added to obtain a desired percentage.

It is advisable to use no more acid than is necessary to clean the fruit. Increasing the amount of acid increases the burden of the rinsing process as will be pointed out later in this publication. For most residues occurring on

Virginia apples, two to three gallons of acid per 100 gallons of water is sufficient; that is, the acid solution should test around 0.7 to about 1.08 percent acid. For light residues or residues very easily removed, one gallon of acid in 100 gallons of water is sufficient. Against heavy residues, a solution containing 1.5 percent acid has been more efficient than weaker solutions. A number of investigators have shown that increasing the concentration of

Table 2.—Relation of schedule of sprays containing cryolite (sodium fluoaluminate) to the fluorine residue on the apples when picked in early October.

Number of sprays containing cryolite, date of each application, amount per 100 gals.	Variety	Fluorine residue (Grain per pound)	
		Series A	Series B
One spray (1935)			
June 18, cryolite 4 lbs., fish oil 1 pt.	Gano	.006	.005
Cryolite 4 lbs., Orthol-K emulsion 3 qts.	Baldwin	.007	.005
Two sprays (1935)			
June 18, cryolite 4 lbs., fish oil 1 pt. July 20, cryolite 4 lbs., fish oil 1 pt.	Gano	.010	.008
Three sprays (1935)			
June 18, cryolite 4 lbs., fish oil 1 pt. July 20, cryolite 4 lbs., fish oil 1 pt. July 25, cryolite 4 lbs., fish oil 1 pt.	Gano	.019	.013
Three sprays (1934)			
June 20, cryolite 4 lbs., fish oil 1 qt. June 29, cryolite 4 lbs., fish oil 1 qt. July 26, cryolite 4 lbs.	Ben Davis	.030	.022
Four sprays (1935)			
June 15, cryolite 4 lbs., fish oil 1 pt. July 1, cryolite 4 lbs., fish oil 1 pt. July 20, cryolite 4 lbs., fish oil 1 pt. Aug. 3, cryolite 4 lbs.	York Imperial[1]	.011	
Four sprays (1934)			
June 19, cryolite 4 lbs., fish oil 1 qt. July 18, cryolite 4 lbs. July 26, cryolite 4 lbs. Aug. 3, cryolite 4 lbs.	York Imperial	.028	.051[2]

[1]Large apples, 2¾ inches up.
[2]Apples (2¼ inches) selected for conspicuous residue.

Table 3.—Dilution table for hydrochloric acid, showing approximate percentage of acid in the diluted solution when different amounts of hydrochloric acid (commercial grade, 20° Baume, about 32 percent acid by weight) are added to 100 gallons of water.

Amount of acid added	Acid in the diluted solution	Amount of acid added	Acid in the diluted solution
Quarts	*Percent*	*Quarts*	*Percent*
4	0.36	11	.099
5	0.45	12	1.08
6	0.54	13	1.16
7	0.63	14	1.25
8	0.72	15	1.33
9	0.81	16	1.42
10	0.90	17	1.50

hydrochloric acid in excess of 1.5 percent did not increase the efficiency of removal in proportion.

The acid tank should be drained at the end of each day's work, if 1000 bushels or more of apples have been washed during the day. This practice will prevent the accumulation of excessive amounts of soluble arsenic in the washing solution and thus assist in reducing the hazard of arsenical injury to improperly rinsed apples. When draining the acid tank the acid can be neutralized by running the solution through a box containing lime, marl, or limestone dust.

Method of determining the percentage of acid in the washing solution.—The pieces of apparatus needed for making the test are as follows:

One 10 cc bulb pipette
One 10 cc measuring pipette graduated in 0.1 cc
One bottle or cup

The testing solution may be prepared at a drug store where accurate balances are available. The solution is prepared by dissolving 23 grams of soda (sodium bicarbonate) in 1000 cubic centimeters of water and adding enough methyl orange to give the solution a yellow color. Steps in making the test are as follows:

1. Fill the bulb pipette with the acid solution by placing the end of the pipette in the acid tank and sucking the acid solution into the pipette. Quickly place the finger over the upper end of the pipette when the column of acid solution rises above the ring marked on the upper part of the pipette.

2. Release the finger enough to allow the acid solution to flow out slowly until the top of the liquid column is even with the mark on the pipette.

3. Allow the contents of the pipette to flow into the bottle or cup. Use the bulb pipette for the acid solution only.

4. Fill the measuring pipette with the testing solution and adjust the level of the liquid to the zero (0.0) mark.

5. Let the testing solution flow slowly from the measuring pipette into the bottle or cup containing the sample of acid solution. Gently shake the bottle or cup during the operation. Stop the flow of the testing solution at the point where the acid solution changes from red to yellow.

6. On the graduated scale of the measuring pipette read the number of cubic centimeters of testing solution used. This reading shows the percentage of acid in the washing solution. For example, if the top of the column of testing solution remaining in the pipette stands at 3, the acid solution contains 0.30 percent acid; if the testing solution stands at 6.5, the acid solution contains 0.65 percent acid; if it stands at 10, the acid solution contains 1.0 percent acid. It is necessary to fill the measuring pipette with testing solution a second time, if the acid solution contains more than 1 percent acid.

The water rinse.—The importance of an adequate fresh water rinse has been emphasized repeatedly. According to studies made by the U. S. Department of Agriculture (Tech. Bul. 245) injury from an inadequate rinse may be due to soluble arsenic on the fruit and especially in the calyx-end causing the calyx-area to turn black (Fig. 1), or to hydrochloric acid remaining on any part of the apple. Wherever drops of the acid solution evaporate, the acid increases in concentration and at that point, the skin is bleached to tan or yellow color and the area becomes depressed and soft (Fig. 1). When sufficient arsenic is present the area will turn black. This usually occurs in the calyx-end only.

During the seasons of 1934 and 1935, the operation of several types of washing machines was investigated with special reference to efficiency of rinsing the fruit. These investigations were made while the machines were engaged in the regular operations of fruit washing. The tests made on the 10 washers and reported in Table 4 represent about the range of operating conditions found during the past two years. By operating conditions we mean the strength of the acid washing solution used, the amount of fruit washed, and the volume of fresh water used per minute. In the flood washers the rinse water was tested for acidity by dipping blue litmus paper in the water as it was pumped over the apples. The moisture remaining on the apples and especially in the calyx-end was also tested for acidity after the fruit had passed on to the grader. When the moisture on the fruit showed no acid reaction by the litmus paper test, it was concluded that the water rinse was adequate. On the other hand, if a distinct acid reaction was obtained (the blue litmus paper turns red in the presence of acid), it was evident that the water rinse was not

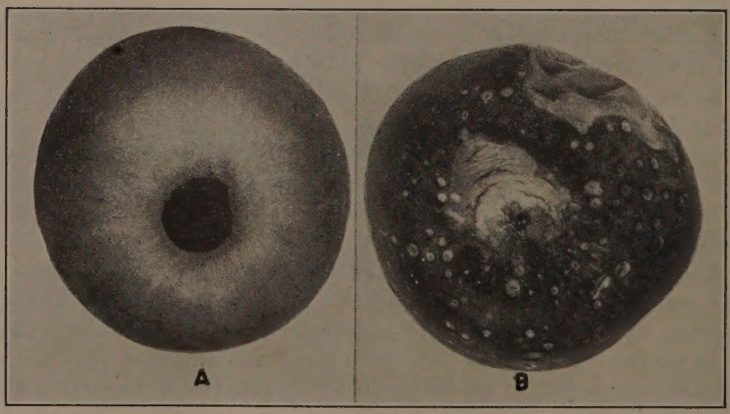

Figure 1.—An inadequate water rinse for washed apples may result in (A) black calyx-end due to soluble arsenic, or (B) tan-colored, soft, depressed areas from hydrochloric acid remaining on the fruit.

sufficient to remove all of the acid and consequently the arsenic dissolved therein.

In the flotation washers the rinse water was tested for acidity within 8 to 12 inches of the end where the fruit leaves the washer; or, in other words, near the point where the fresh water enters the rinse tank. When the water at this end of the rinse tank did not show an acid reaction, the moisture remaining on the washed apples also showed no acid reaction. On the other hand, if the rinse water was acid near the point where the fruit was conveyed out of the rinse tank, a distinct acid reaction could be detected by testing the moisture remaining in the calyx-end of the apples after the fruit had passed to

Table 4.—Operation of apple washers in relation to correction of acidity of the fresh water rinse by the addition of hydrated lime, or by the use of sufficient fresh water when available.

Desig. of washer	Type of washer, capacity of acid and water tanks, length of time fruit remained in the acid bath	Percent acid	Bushels of apples washed per minute	Volume of fresh water per minute	Amount of lime added to the water rinse	Length of time rinse water remained alkaline or neutral[1]
				Gallons	*Pounds*	*Minutes*
1	Flotation, same conveyor for acid tank (150 gals.) and water tank (76 gals.), 45 sec.	1.35	3	3	1	18—20
		1.35	3	3	1½	25
		1.35	3	3	2	25—30
		1.35	3	1⅛	1	30
		1.35	3	3½	1	25
		1.35	3	6	No lime needed	
2	Flotation, separate conveyor for acid tank (240 gals.) and water tank (128 gals.), 60 sec.	0.7	3	3	No lime needed	
		1.1	3	3	2	60
		1.25	3	3	2	50—60
		1.4	3	3	1	38
		1.4	3	3	3¼	75
		1.4	3	3	2	100[2]
3	Same type and size as No. 1, 45 sec.	0.45	2	2	1	45
		1.25	2	2	1	22
		1.25	2	2	1½	25
		1.25	2	2	2	30
		1.25	2	2	2¼	30
4	Flotation, separate conveyor for acid tank (100 gals.) and water tank (50 gals.), 45 sec.	1.25	2	2	¼	60
		1.25	2	2	½	110
		1.25	2	2	1	140
		1.25	2	2	1½	165
5	Flood, shuffleboard conveyor, acid tank (325 gals.), water tank (200 gals.), 34 sec.	1.25	4	3	1	50—55
		1.25	4	3	2	100
		1.25	4	3	3¼	165
		1.25	5	5½	6	600 or more
6	Same type and size as No. 1, 45 sec.	1.5	3	6½	No lime needed	
7	Same type and size as No. 2, 45 sec.	1.0	4	4	No lime needed	
8	Brush, walkover conveyor, acid tank (200 gals.) and water tank (150 gals.), 20 sec.	0.8	2	3½	No lime needed	
9	Flotation, paddle conveyors, acid tank (200 gals.) and water tank (100 gals.), 60 sec.	0.35	3	5	No lime needed	
10	Same type and size as No. 9, 60 sec.	0.33	2	2½	No lime needed	

[1]By litmus paper test near point where apples leave the water, and also by litmus paper test in calyx-end of apples after the fruit has left the washing machine.

[2]Rinse water agitated at 5-minute intervals throughout period of test.

the grader. As a rule, when the calyx-end was touched by the tongue, the characteristic salty taste imparted by the weak acid could be detected.

It will be seen from a study of the data in Table 4 that the volume of fresh rinse water required varied with the strength of the acid bath as well as with the type of washer used. In other words, it was not simply a matter of using a certain amount of water per bushel of apples washed. There was sufficient fresh water to remove the acid from the fruit in washers Nos. 6 to 10 inclusive. In these machines, however, the volume of fresh water per bushel of apples washed was not the same. For example, there were two gallons of fresh water for each bushel of apples washed in washer No. 6 but only one gallon per bushel washed in washer No. 7. In operating washer No. 2 one gallon of water per bushel of fruit was an adequate rinse as long as the strength of the acid bath was maintained at 0.7 percent acid, but when increased to 1.1 percent acid the rinse was inadequate and hydrated lime was added to neutralize the remaining acidity. On the other hand, washer No. 3, when operating with a weak acid solution (0.45 percent acid) and a fresh water rinse of one gallon per bushel of washed fruit, did not rinse the apples sufficiently to remove all of the acid, and because of this, the addition of one pound of lime was required every 45 minutes. When the strength of the washing solution was increased to 1.25 percent acid, it was necessary to add one pound of lime every 22 minutes to the rinse tank.

It will be observed that flotation washers with separate conveyors for the acid and water tanks (washers Nos. 2 and 4) required less lime, or the addi-

Figure 2.—Flotation washer moved from packing shed into the orchard near an adequate supply of water.

tion of lime less frequently, to neutralize the acid on the washed fruit, than was required for flotation washers (Nos. 1 and 3) in which the conveyor as well as the fruit passed from the acid tank into the water rinse. There was no means on any of the flotation washers for rinsing the fruit between the acid tank and the water tank. Other things being equal, the build-up of acid in the water rinse is in proportion to the carry-over from the acid tank; therefore, it was not surprising to find less acid in the rinse tanks of flotation washers, in which only the apples passed from the acid bath into the water rinse.

It cannot be said from the data obtained that a flood washer may require less fresh rinse water than a flotation washer of the type in which only the fruit passes from the acid bath into the water rinse.

"How much fresh water is required to rinse the fruit sufficiently to eliminate the acid from the washed apples?" It is apparent from Table 4 that the required volume of water varied with operating conditions and type of washer used. It appears, however, from ordinary operating conditions that 6 to 6.5 gallons of water per minute has been sufficient. Whether a smaller volume of water will be adequate will depend on the strength of the acid bath, the rate of washing, and the type of machine used as indicated in Table 4.

"How much hydrated lime must be added to the water rinse to neutralize the acid remaining on the apples when there is not sufficient rinse water available?" The amount of lime required and the frequency of adding it will vary with the operating conditions and the type of washer used. In flotation wash-

Figure 3.—Flotation washer with the same conveyor for the acid tank and the water tank.

ers with the same conveyor for both acid and water tanks, and no provision for rinsing the fruit and conveyor between the tanks, it may be necessary to add 1 pound of lime (1 quart dry measure) every 20 or 25 minutes, while in other types of flotation washers the same amount of lime may remain effective two to four times longer. The amount and frequency with which lime was added in actual operations and the duration of effectiveness are shown in Table 4. No visible residue remained on the fruit when the concentration of lime in the rinse tank did not exceed 3 pounds per 100 gallons.

After the lime settled to the bottom of the rinse tank it no longer served to neutralize the acid on the apples. By stirring up the lime which had settled it was possible to prolong considerably its effectiveness. For example, in washer No. 2 it was observed that 2 pounds of lime neutralized the rinse for about an hour, at which time the lime had settled to the bottom. Scraping a paddle over the bottom a few times brought the lime into suspension and prolonged its effectiveness for an additional 30 to 40 minutes. Agitating the rinse water at five-minute intervals from the time of adding the lime prolonged its effectiveness about as much as waiting until the lime had settled before agitation.

A grower can determine when more lime is needed by using the litmus paper test. Touch the calyx-end of an occasional apple as soon as the fruit has left the washing machine. If the blue paper turns red, lime is needed, or if a considerable quantity of lime has settled to the bottom of the rinse tank, it should be stirred into suspension. As long as the rinse water appears

Figure 4.—Flotation washer with separate conveyors for the acid tank on right and the water rinse tank on left.

slightly cloudy or milky from lime in suspension its effectiveness continues and no additional lime is needed.

Heating the acid solution and cost of heating.—Various methods of heating the acid bath have been tried, but experience has shown that the most practical method is by the injection of steam into the acid solution. Steam is piped from a boiler (Fig. 5) into the washer. The flow of steam is regulated by a valve at the washer, so that it is a simple matter to keep the temperature of the acid solution between 100° and 110° F. Temperatures considerably below 100° F. add little of practical value to the efficiency of the washing solution. Temperatures above 110° F. increase the efficiency considerably but the hazard of heat injury is also increased. Experience has shown that varieties of apples commonly grown in Virginia can remain in an acid washing solution at 110° F. for 45 to 60 seconds without injury. Investigations in Maryland (Md. Exp. Sta. Bul. 368) indicate that the Jonathan apple is somewhat more susceptible to heat injury than other varieties common in this region, and for this variety a temperature limit of 100° F. with an exposure of 1 minute was considered safe. The McIntosh apple, grown to a limited extent in northern Virginia, is perhaps more susceptible to heat injury than any other variety grown in the state. According to experiments on washing this variety in New York (Cornell Exp. Sta. Bul. 604) light injury was caused by acid temperatures of 100° F. and a safe temperature limit was from 90° to 95° F.

The cost of heating the acid bath varied somewhat with the number of bushels of apples washed; but, in any case, the cost was low. Probably the

Figure 5.—For the purpose of heating the acid solution, steam from the boiler of a traction engine is piped underground to the washer in the packing shed.

extremes in cost range are shown in Table 5. These figures were based on coal at $6.50 per ton, $2.00 per day for the fireman and a rental charge of $25.00 a season for a boiler, or $20.00 per year depreciation and repairs on heating equipment owned by the grower. Each boiler consumed about one ton of coal per week when operating full time on a 10-hour day. A smaller heating outfit for a single washer might reduce the cost of heating somewhat.

Table 5.—Cost of heating the acid solution by injecting steam directly into the acid division of the washer. Data taken from three orchards in 1935.

Number of bushels of apples washed	Approximate number of bushels washed per day	Total cost, including depreciation or rent of heating equipment	Approximate cost per 100 bushels of apples washed
		Dollars	*Cents*
8,000	500	71.50	89.4
43,000	2,000	94.00	21.9
200,000	4,200	174.00	8.7

Relative efficiency of different kinds of washing machines.—The question is frequently asked, "Will one kind of washer remove more residue than another?" Eight lots of apples were selected for washing in the four kinds of washers used in Virginia. Lot 1 was sprayed with oil emulsion, 1 percent, plus nicotine bentonite on July 1, following a schedule of lead arsenate in the calyx and 3 cover sprays to which summer oil was added in the second and third covers in June. Lots 2 and 3 also received a schedule of lead-arsenate sprays to which summer oil emulsion was added in the second and third covers. Lots 4 to 8 received lead arsenate or a combination of lead arsenate and calcium arsenate; but, in no case, was oil used in any of the sprays. The washing machines used included a flotation washer, a flood washer with shuffleboard conveyor, an oscillating fiber-brush washer, and a 1935 model underbrush washer, the brushes being of rubber construction. In each of the machines the fruit was washed at the speed used in nearly all washing operations in Virginia, that is, in the flotation washer the apples remained in the acid bath 45 seconds, and in the other washers, all operated at their regular speed, the fruit passed through the acid bath in somewhat shorter time.

It will be seen (Table 6) that none of the washers cleaned the fruit of Lots 1 to 3 to within the tolerance for lead and arsenic, but the brush washers removed a greater percentage of the residues than the other machines while the flotation washer removed the least amount. The omission of summer oil from the arsenical sprays of Lots 4 to 8 simplified cleaning and the inclusion of Bordeaux mixture made residue removal a relatively easy matter. Although the flotation washer ranked slightly below the other machines in average per-

Table 6.—Relative efficiency of different kinds of washing machines in removing lead and arsenic residues. Apples washed in 1 percent hydrochloric acid solution. Temperature of acid solution ranged from 50 to 59 degrees F. The results are stated in grains of arsenic and lead per pound of fruit before and after washing with the percentages of residue removed.

Schedule of sprays, date of last arsenical spray, amount of materials per 100 gals. Lead arsenate 3 lbs. all schedules, except No. 6. (LA=lead arsenate)	Variety	Check, not washed		Kind of washer, residue remaining on the washed fruit and percent of residue removed							
				Flotation washer		Oscillating brush washer		Underbrush washer		Flood washer	
		Arsenic	Lead	Arsenic	Lead	Arsenic	Lead	Arsenic	Lead	Arsenic	Lead
1. LA in 3 covers (June 19), oil emulsion 4 qts. 2nd and 3rd covers. Oil-nicotine (July 1).	Ben Davis	.033	.058	.022 33%	.036 38%	.007 79%	.013 77%	.010 70%	.019 67%	.011 67%	.021 64%
2. LA in 6 covers, (Aug. 3) with oil emulsion 3 qts. on June 4 and 17.	York Imperial	.128	.268	.041 68%	.084 69%	.020 84%	.036 86%	.017 87%	.028 89%	.027 79%	.050 81%
3. LA in 4 covers (July 25) with oil emulsion 3 qts. on June 5 and 18.	Gano	.069	.148	.015 78%	.025 83%	.018 73%	.030 80%	.013 81%	.021 86%	.019 72%	.042 72%
Average residue removed	------	------	------	60%	63%	79%	81%	79%	81%	72%	72%
4. LA in 6 covers (Aug. 3).	York Imperial	.104	.193	.018 83%	.030 84%	.019 82%	.025 87%	.015 85%	.028 85%	.010 90%	.018 85%
5. LA and soap .5 lb. in 6 covers (Aug. 3).	York Imperial	.094	.170	.017 82%	.028 83%	.017 82%	.028 83%			.014 85%	.025 85%
6. LA 1.5 lbs. and calcium arsenate 2 lbs. with Bordeaux 2–4–100 in 6 covers (Aug. 3).	York Imperial	.080	.084	.006 92%	.009 89%	.007 91%	.008 90%			.008 90%	.011 87%
7. LA in 4 covers (July 25).	Gano	.058	.094	.015 74%	.023 75%	.011 81%	.013 86%	.010 82%	.019 79%	.010 82%	.019 79%
8. LA in 4 covers (July 31), Bordeaux 2–4–100 in 2nd and 3rd covers.	Gano	.022	.044	.006 73%	.011 75%	.003 86%	.005 88%			.003 86%	.006 86%
Average residue removed	------	------	------	81%	81%	84%	87%	83%	82%	86%	84%

centage of residue removed from Lots 4 to 8, it is apparent that there was no practical difference in the efficiency of any of the washers. As a rule, when one machine removed the residues within tolerance the other washers did also.

The tests indicate that the brush washers are somewhat more efficient than the other types of washers when washing fruit which carried residues difficult to remove such as the oil-lead-arsenate combination. On the other hand, fruit which carries residues not especially difficult to remove, may be washed as satisfactorily in one kind of washer as in another.

Removal of Spray Residues in 1934 and 1935

Lead and arsenic residues.—It has already been pointed out (Table 6) that the inclusion of Bordeaux mixture simplified the problem of residue removal while summer oil made removal more difficult. According to our experience of 1934 (Table 7) the use of oil plus Bordeaux mixture in the first two cover sprays did not make residue removal any more difficult than a straight lead-arsenate schedule. Further evidence to substantiate the influence of oil with and without Bordeaux mixture may be found in Table 8. It will be seen in Table 8 that summer oil with lead arsenate and following lead arsenate (schedule 1) increased the difficulty of removing the lead and arsenic residues. At the same time a schedule of lead arsenate alone throughout the season (schedule 2) left residues difficult to remove. Residues from a mixture of calcium arsenate and lead arsenate plus Bordeaux mixture (schedule 7) were easily removed. Likewise the residues from calcium arsenate plus Bordeaux mixture (schedule 9) were easily removed in cold acid solutions.

Table 7.—Residue removal from apples which received heavy applications of lead arsenate with and without oil and Bordeaux mixture included in the schedule in 1934. Apples washed in a flotation washer. The results are stated in grains of arsenic and lead per pound of fruit.

Washing solution (Amount per 100 gallons)	Temperature of acid solution	Length of time in acid wash, in seconds	Spray schedule and materials per 100 gallons, date of last spray, and residues on washed fruit							
			Lead arsenate 3 lbs., in 6 covers on York Imperial (Aug. 13) and in 5 covers on Ben Davis (July 26)				Lead arsenate 3 lbs., in 6 covers on York Imperial (Aug. 13) and in 5 covers on Ben Davis (July 26) plus 1 gallon oil emulsion and Bordeaux (1–3–100) in 1st and 2nd covers			
			York Imperial		Ben Davis		York Imperial		Ben Davis	
			Arsenic	Lead	Arsenic	Lead	Arsenic	Lead	Arsenic	Lead
HCl 1%	64—69	45	.015	.029	.016	.030	.012	.025	------	------
HCl 1%	69	60	------	------	------	------	.011	.023	------	------
HCl 1%, Vatsol 4 lbs.	69	60	------	------	------	------	.009	.017	------	------
HCl 1%, Vatsol 8 lbs.	64—69	45	.014	.027	.013	.027	.009	.021	------	------
HCl 1%, Areskap 10 lbs. (1 gal.)	64—69	45	.017	.032	.014	.028	.012[1]	.023[1]	------	------
HCl 1%, salt 8 lbs.	66	45	.020	.036	.027	.048	.012	.020	.021	.034
HCl 1%, Vatsol 8 lbs., salt 8 lbs.	66	45	.012	.022	------	------	.009	.014	.008	.012
HCl 1%	97	45	------	------	------	------	.009	.016	.008	.016
HCl 1%	97	60	------	------	------	------	.008	.017	------	------
HCl 1%, salt 16 lbs.	105	45	.012	.023	.010	.021	.008	.012	.007	.010
HCl 1%, Vatsol 4 lbs., salt 16 lbs.	110	45	.009	.018	.006	.009	.006	.005	.007	.011
HCl 1%, Aresket 4 lbs., salt 16 lbs.	90	45	.010	.017	.009	.014	.007	.010	.006	.006
HCl 1.5%	97	45	------	------	------	------	.008	.016	.008	.014
HCl 1.5%	97	60	------	------	------	------	.007	.015	------	------
HCl 1.5%	64—69	45	.009	.021	.013	.029	.011[1]	.022[1]	------	------
HCl 1.5%, Vatsol 8 lbs.	69	45	------	------	------	------	.007	.011	------	------
HCl 1.5%, Areskap 10 lbs. (1 gal.)	69	45	------	------	------	------	.007	.012	------	------
Sodium silicate 75 lbs., and soap	66	45	.022	.045	.016	.044	.026	.048	.020	.040
Sodium silicate 75 lbs., Vatsol 4 lbs.	66	45	.015	.028	.019	.030	.011	.021	.014	.027
Sodium silicate 75 lbs., and soap	110	45	.016	.040	.013	.036	.013	.028	.013	.028
Check, not washed	------	----	.084	.180	.052	.100	.072	.132	.055	.090

[1]Apples in acid wash 60 seconds.

Table 8.—Relation of various spray schedules in 1935 to the residue occurring on the apples at picking time (October) and also after washing in a flotation washer. The results are stated in grains of arsenic and lead per pound of fruit.

Spray schedule with amount of materials per 100 gals ; date of last spray; washing solution used. (LA=lead arsenate 3 lbs., CA=calcium arsenate 4 lbs., Bdx=Bordeaux mixture)	Variety	Temp. of acid bath	Length of time in acid wash and residue on washed fruit			
			60 seconds		45 seconds	
		(°F.)	Arsenic	Lead	Arsenic	Lead
1. LA 3 covers (June 20) oil emulsion 4 qts. in 2nd and 3rd covers, oil-nicotine without LA (July 1).						
Unwashed	Ben Davis		.033	.058		
HCl 1%	" "	64			.019	.032
HCl 1.5%	" "	64			.012	.025
HCl 1%	" "	110			.010	.019
HCl 1%, Vatsol powder 6 lbs.	" "	109	.003	.005		
Sodium silicate 75 lbs., then HCl 1%	" "	110	.004	.004	.005	.006
Sodium silicate 75 lbs., HCl 1%, Vatsol 6 lbs.	" "	110	.003	.004	.006	.006
Sodium silicate 75 lbs., HCl 1%, Vatsol 6 lbs.	" "	100	.005	.005	.008	.011
2. LA 6 covers (Aug. 3). Unwashed	York Imperial		.104	.193		
HCl 1%	" "	60	.023	.048		
HCl 1%	" "	110	.011	.022	.019	.030
HCl 1%	" "	110	.007[1]	.015[1]		
HCl 1%, Vatsol powder 6 lbs.	" "	110			.016	.028
HCl 1%, Areskap powder 5 lbs.	" "	60	.016	.027		
HCl 1%, Areskap powder 5 lbs.	" "	60	.012[1]	.023[1]		
3. LA 6 covers (Aug. 3) with oil emulsion in 2nd and 3rd covers. Unwashed	York Imperial		.128	.268		
HCl 1%	" "	64	.020	.044	.023	.054
HCl 1%	" "	110	.011[1]	.019[1]		
HCl 1%, Vatsol powder 6 lbs.	" "	110	.018	.030	.020	.036
HCl 1%, Areskap powder 5 lbs.	" "	110	.010	.019	.016	.028
4. LA 6 covers (Aug. 3) with oil 3% and soap .5 lb. first 3 covers. Unwashed	York Imperial		.115	.188		
HCl 1%	" "	64	.043	.084		
HCl 1%	" "	110	.021	.036	.025	.046
HCl 1%, Vatsol powder 6 lbs.	" "	100	.008	.010	.014	.025
HCl 1%, Areskap powder 5 lbs.	" "	95	.005	.009		
5. LA 6 covers (Aug. 3) with soap .5 lb., Bdx in 3rd cover. Unwashed	York Imperial		.094	.170		
HCl 1%	" "	60	.023	.056		
HCl 1%	" "	110	.007	.011	.009	.015
HCl 1%, Areskap (1 gal.) 10 lbs.	" "	62	.020	.038	.022	.032
6. LA[2] 6 covers (Aug. 3) with Bdx in 3rd cover. Unwashed	York Imperial		.103	.192		
HCl 1%	" "	60			.024	.050
Unwashed	Gano		.069	.134		
HCl 1%	"	62			.008	.017
7. LA 1st cover, then on Yorks LA 1.5-CA 2 lbs. in 5 covers (Aug. 3), on Gano LA 1.5-CA 1.5 lbs. in 3 cov rs (July 25), Bdx all but 1st cover. Unwashed	York Imperial		.080	.084		
HCl 1%	" "	60	.008	.011	.008	.011
Unwashed	Gano		.045	.024		
HCl 1%	"	62			.006	.008
8. LA 4 covers (July 25), oil emulsion 4 qts. in 2nd and 3rd covers, Bdx 2nd and 4th covers. Unwashed	York Imperial		.022	.047		
HCl 1%	" "	60			.007	.014
9. LA 1st cover, then on Yorks CA and Bdx in 5 covers (Aug. 3), on Gano CA and Bdx in 4 covers (July 25). Unwashed	York Imperial		.053	.026		
HCl 1%	" "	64			.005	.002
Unwashed	Gano		.054	.008		
HCl 1%	"	62			.004	.002
10. LA 4 covers (July 25). Unwashed	Gano		.058	.094		
HCl 1%	"	60	.015	.031		
HCl 1.5%	"	60	.009	.016		
HCl 1%, Vatsol powder 6 lbs.	"	62	.008	.013		
HCl 1%, Areskap powder 5 lbs.	"	62	.008	.011	.011	.019
HCl 1%	"	110	.005	.010	.007	.011

[1]Fruit in acid wash 2 minutes.
[2]Lead arsenate contained small amount of casein.

That the use of soap with lead arsenate did not appear to increase the difficulties of removal is shown by comparing the results of washing apples from schedules 5 and 2 of Table 8. Lead arsenate from sprays containing a small amount of casein (schedule 6) did not appear more difficult to remove than ordinary lead arsenate (schedule 2).

Wetting agents.—Growers sometimes ask, "Can I use a wetting agent in the acid solution instead of heating the solution?" A study of Tables 7 and 8 shows that the wetting agents added little or nothing of practical value to the efficiency of unheated acid solutions when the apples remained in the acid bath only 45 to 60 seconds. When the unheated acid solution failed to remove the residues to within tolerance, the addition of a wetting agent did not sufficiently increase efficiency of removal to accomplish the desired results. Heating the acid solution invariably increased the efficiency of residue removal and, as a rule, was sufficient to clean the fruit to within tolerance without the aid of wetting agents. In certain instances, however, especially where considerable oil had been used, the addition of a wetting agent to the heated acid solution was necessary (for example, schedule 4 of Table 8).

Washing solution.—Under our conditions hydrochloric acid is preferable to any other material yet used. Sodium silicate was distinctly less effective in removing residues from fruit which had received a considerable amount of oil plus lead arsenate and following lead arsenate.

Fluorine residue.—According to the results obtained during the past two seasons, fluorine residue from three or four cryolite sprays may be removed by the same washing treatment employed for the removal of lead arsenate. It should be stated, however, that no sticker was used in the fourth spray, and when as much as 1 quart of fish oil per 100 gallons was used as a sticker its use was confined to the two cryolite sprays applied in June. For details of the spray schedules see Table 2. A study of Table 9 shows that an unheated acid solution was not consistently effective in cleaning the fruit to tolerance; namely, 0.010 grain of fluorine per pound of fruit. In 1935, however, the fluorine residue was not so heavy as in 1934 and the unheated acid solution was effective in cleaning the apples in all types of washers available for the tests.

The use of wetting agents in the unheated acid solution did not result in increased efficiency of removal, and in some cases appeared to decrease the effectiveness of the acid wash in reducing the fluorine residue. Heating the acid solution increased efficiency of removal. An unheated solution of sodium silicate was of little or no value and when heated to 110° F. was less effective than a heated acid solution. Brushing or wiping the fruit in the season of 1934 failed to clean any of the samples to the limit of the tolerance.

Table 9.—Removal of fluorine residue from apples in 1934 and 1935. (Apples 2¼ — 2½ inches, except where noted otherwise.)

Treatment for removal of fluorine (In 1934 all washing tests made in a flotation washer) Amount of materials used per 100 gallons	Temp. of acid bath (°F.)	Time in acid bath (Sec.)	Fluorine residue in grains per pound of fruit	
			York Imperial	Ben Davis
Season of 1934:				
Check, not washed or wiped			.028	.020
HCl 1%	66	45	.012	
HCl 1%	66	60	.006	.013
HCl 1%, Areskap 10 lbs. (1 gal.)	66	60	.008	.013
HCl 1%, Vatsol 6 lbs.	66	60	.019	
HCl 1%, Vatsol 8 lbs.	66	60		.009
HCl 1.5%, Vatsol 6 lbs.	62	60	.023	
HCl 1%	110	45	.004	.005
HCl 1%	95	60	.007	.007
HCl 1%, Vatsol 6 lbs., salt 16 lbs.	110	45	.013	
HCl 1%, Vatsol 6 lbs., salt 16 lbs.	110	60	.008	
Trescott brush cleaner			.029	
Andy Moe cleaner			.025	
Sodium silicate 75 lbs.	66	60		.020
Sodium silicate 75 lbs.	110	45		.010
Sodium silicate 75 lbs.	110	60		.010
Check, not washed or wiped				.022
HCl 1.5%	110	60		.003
HCl 1.5%, Vatsol 8 lbs.	110	60		.003
Check, not washed or wiped			.051[1]	
Sodium silicate 75 lbs. and soap	110	60	.010[1]	
Check, not washed or wiped (2¼ in. fruit)				.040
Trescott brush cleaner				.019
Season of 1935:				
Check, not washed or wiped (2¾ in. fruit)			.011	
HCl 1%, flotation washer	60	45	.009	
HCl 1%, underbrush washer	56		.008	
Check, not washed or wiped				.019[2]
HCl 1%, flotation washer	50	45		.008[2]
HCl 1%, oscillating brush washer	50			.005[2]
HCl 1%, underbrush washer	56			.008[2]
HCl 1%, flood washer	50			.010[2]

[1]Fruit of this lot (mostly 2¼ — 2½ inch apples) selected for conspicuous residue.
[2]Gano variety.

Summary and Conclusions

Lead arsenate, 3 pounds to 100 gallons of spray solution, applied in commercial orchards in the calyx and two cover sprays ending June 11 or 12 resulted in an average lead residue of 0.019 grain and 0.013 grain in 1934 and 1935, respectively. The maximum lead residue was 0.027 grain per pound of fruit. Usually, however, the residue was within or sufficiently near the present lead tolerance of 0.018 grain per pound to permit cleaning the fruit without washing.

Lead arsenate in the calyx and first cover spray ending May 27 or 28 resulted in an average lead residue of 0.010 grain and 0.012 grain per pound of fruit and a maximum of 0.015 and 0.017 grain per pound in 1934 and 1935, respectively.

One spray of cryolite in June resulted in a maximum fluorine residue of

0.007 grain per pound of fruit. Two cryolite sprays with only 1 pint of fish oil per 100 gallons as a sticker (applied June 18 and July 20) caused a residue equal to the fluorine tolerance of 0.010 grain per pound of fruit.

Fluorine residue from three cryolite sprays ending July 25 and 26 necessitated washing to clean the fruit to within the tolerance.

For removing the residues occurring on most Virginia apples, two to three gallons of hydrochloric acid per 100 gallons of water is adequate. For heavy residues concentrations up to 4½ gallons per 100 gallons of water may be required. For light residues or residues very easily removed, 1 gallon of acid in 100 gallons of water is sufficient.

The amount of fresh water required for adequate rinsing varied with the type or design of the washer, the strength of the acid solution and the rate of washing. Inadequate rinsing may result in arsenical burning at the calyx-end or acid injury wherever the acid solution evaporates on the fruit. Arsenical injury is more likely to occur than acid injury under our conditions.

Fresh water at the rate of 6 to 6½ gallons per minute removed traces of acid from washed apples when the washing solution tested 1.35 to 1.50 percent acid. With weaker acid solutions less fresh water may be required, depending largely upon the operating conditions and the type or design of washer.

Wherever sufficient water is not available for an adequate rinse, the addition of hydrated lime to the rinse tank is advisable for the purpose of neutralizing the acid and converting soluble arsenic into an insoluble form. A schedule of adding lime is given for various washing operations.

Heating the acid solution increased the efficiency of removal to a marked degree. Cost of heating by steam injection ranged from 8.7 cents to 89.4 cents per 100 bushels of apples washed.

When washing apples sprayed with lead arsenate plus oil in some of the cover sprays, brush washers removed a greater percentage of the lead and arsenic residues than other washers, while the flotation washer removed the least amount. None of the machines, when using cold acid solution, cleaned the fruit sufficiently to meet the tolerance.

There was no practical difference in efficiency of residue removal by the flotation washer, flood washer, and the two kinds of brush washers when washing fruit which carried residues not especially difficult to remove.

Wetting agents added little or nothing of practical value to the efficiency of unheated acid solutions when the fruit remained in the acid solution only 45 to 60 seconds. In heated acid solutions the wetting agents increased efficiency of removal.

Bordeaux mixture in the cover sprays made the removal of lead arsenate less difficult; whereas the use of oil with lead arsenate increased the difficulty of removal.

Hydrochloric acid was considerably more efficient than sodium silicate in removing residues of lead, arsenic, and fluorine.